

The Keck Interferometer and the Caltech/JPL Interferometry Science Center

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ISC/Caltech

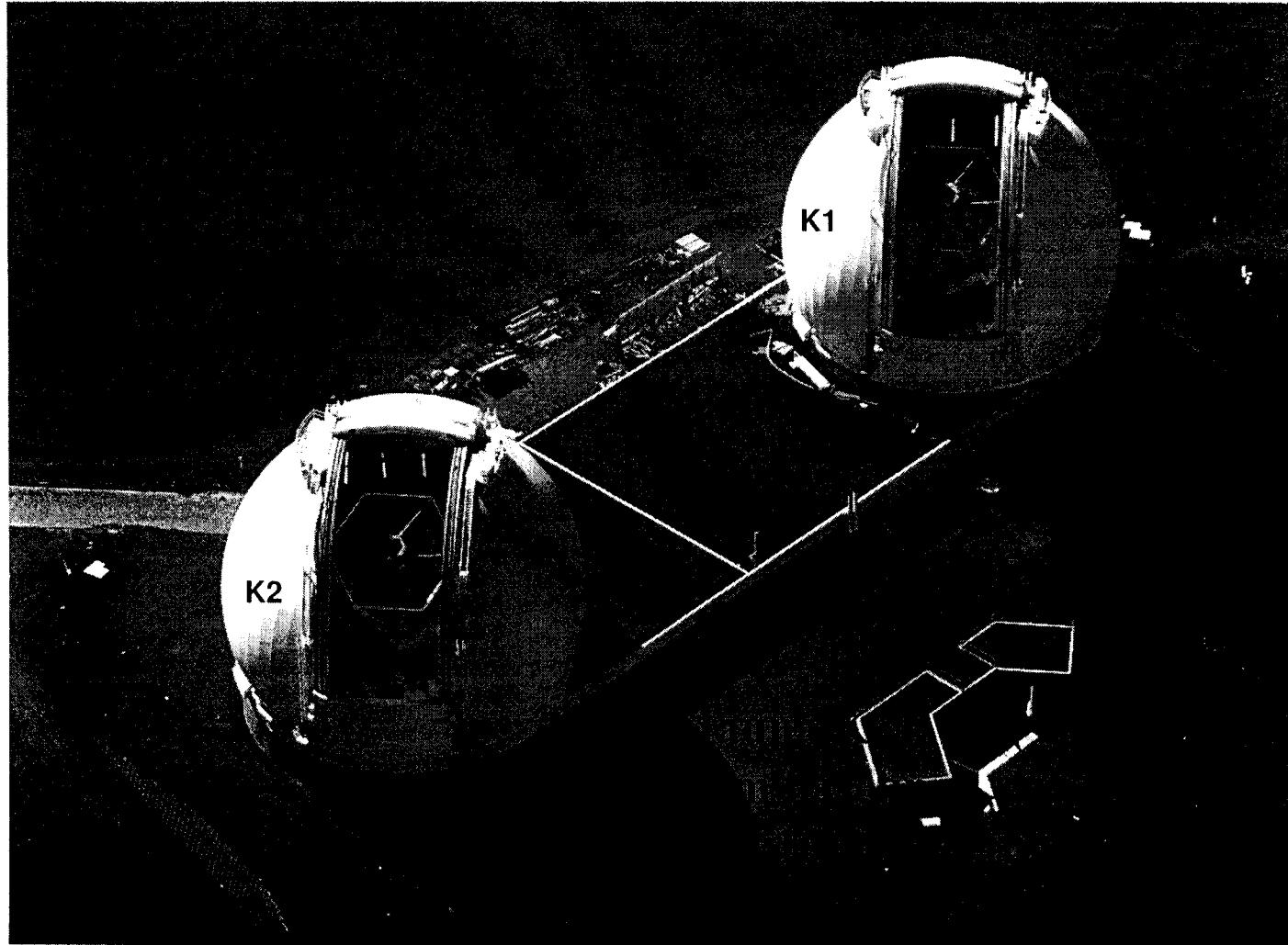


JPL



ISC

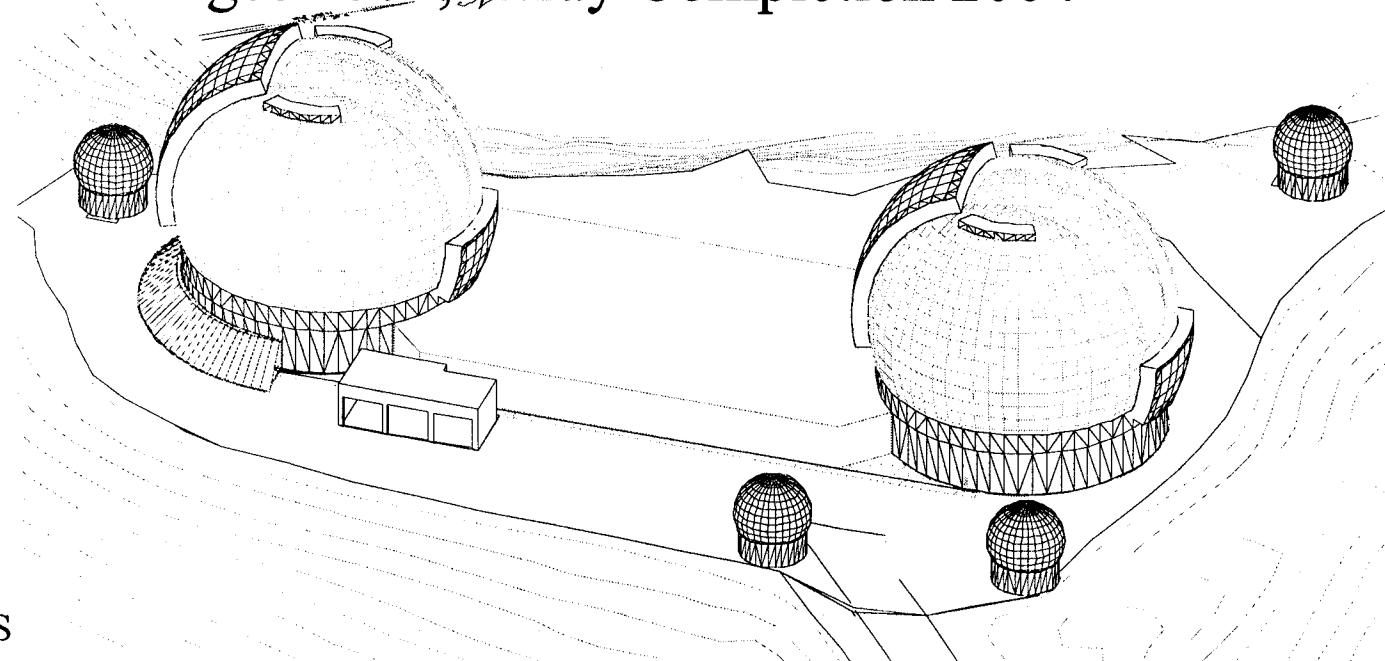
Keck Observatory - Winter 1999



© 1998 Richard Wainscoat

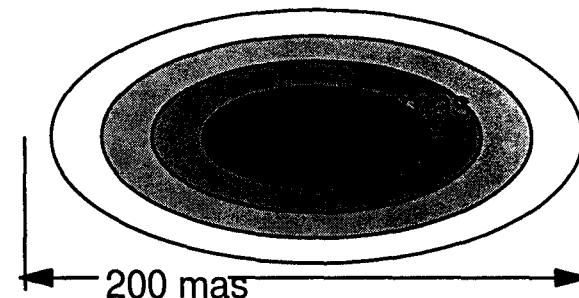
Keck Interferometer (KI)

- Keck Interferometer, Part of NASA's Origins Program (1997)
- Joint Development Effort: JPL, WMKO, and ISC/Caltech
- Phased Development
 - Differential Phase Detection of Hot Exo-Planets (e.g. 51 Pegasi B)
 - Nulling Detection of Exo-Zodiacal Emission
 - Astrometric Detection of Exo-Planets Orbiting Nearby Stars
 - Synthesis Imaging Capability
- First Fringes 2001; Array Completion 2004

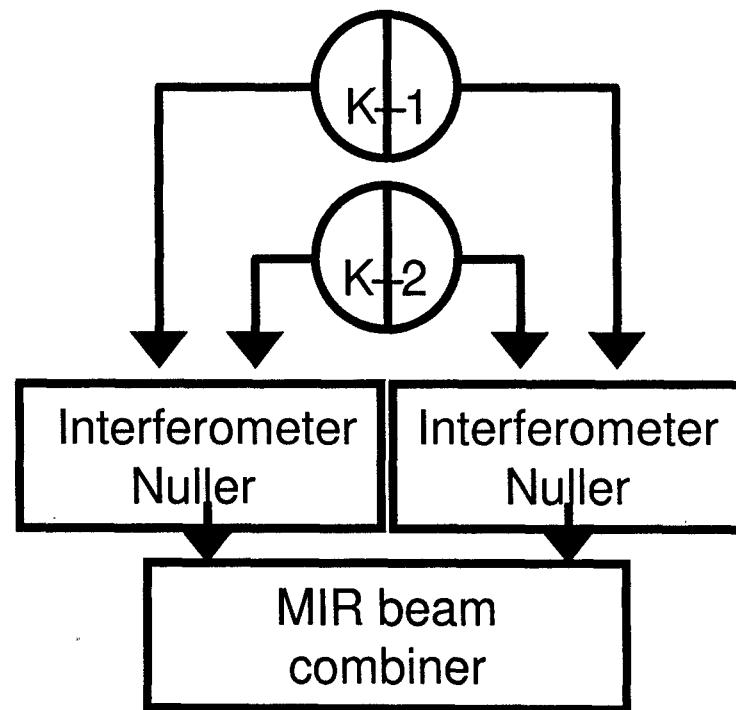


Nulling for Exozodiacal Dust Detection

- Characterize exozodiacal emission around nearby stars to < 10 solar-system equivalents
- Observational issues
 - Strong light from central star
 - Weak exozodiacal signal (10^{-4})
 - Strong 10- μm background
- Approach: Multi-baseline nulling
 - Send two beams to basement from each telescope
 - Null star on each of two K1-K2 baselines
 - Perform “standard” interferometry on the two nulled outputs

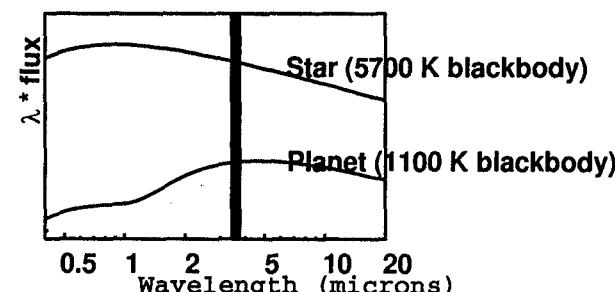
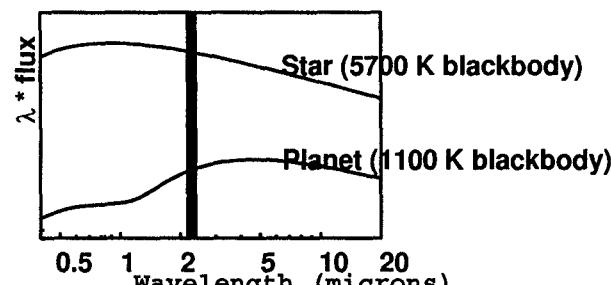
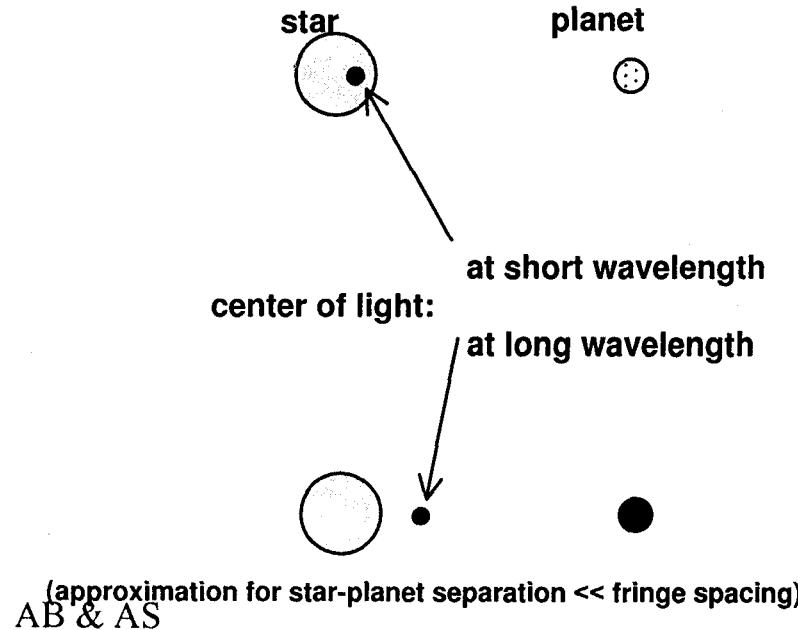


1AU radius disk at 10 pc



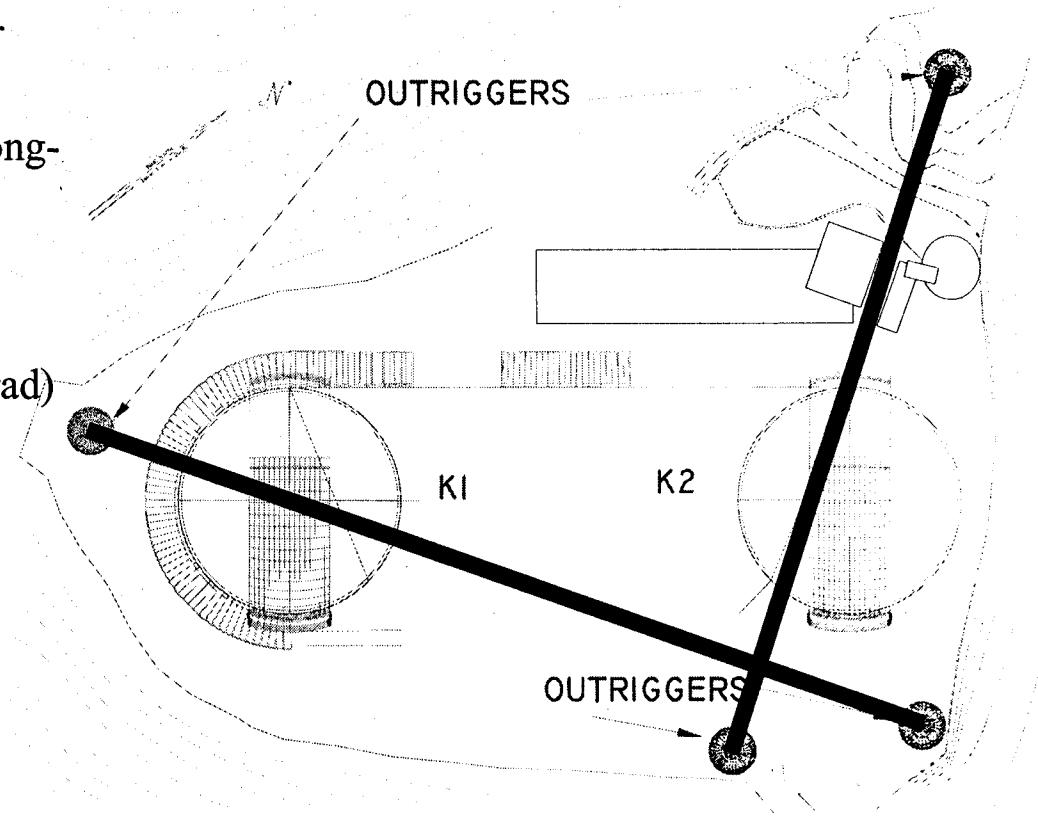
Detecting Hot Jupiters With Differential Phase

- Scientific objectives
 - Direct detection of warm Jovian planets
 - Characterize orbital parameters (mass), low-dispersion spectra
- Observational issues
 - Large color difference between components
=> wavelength-dependent centroid

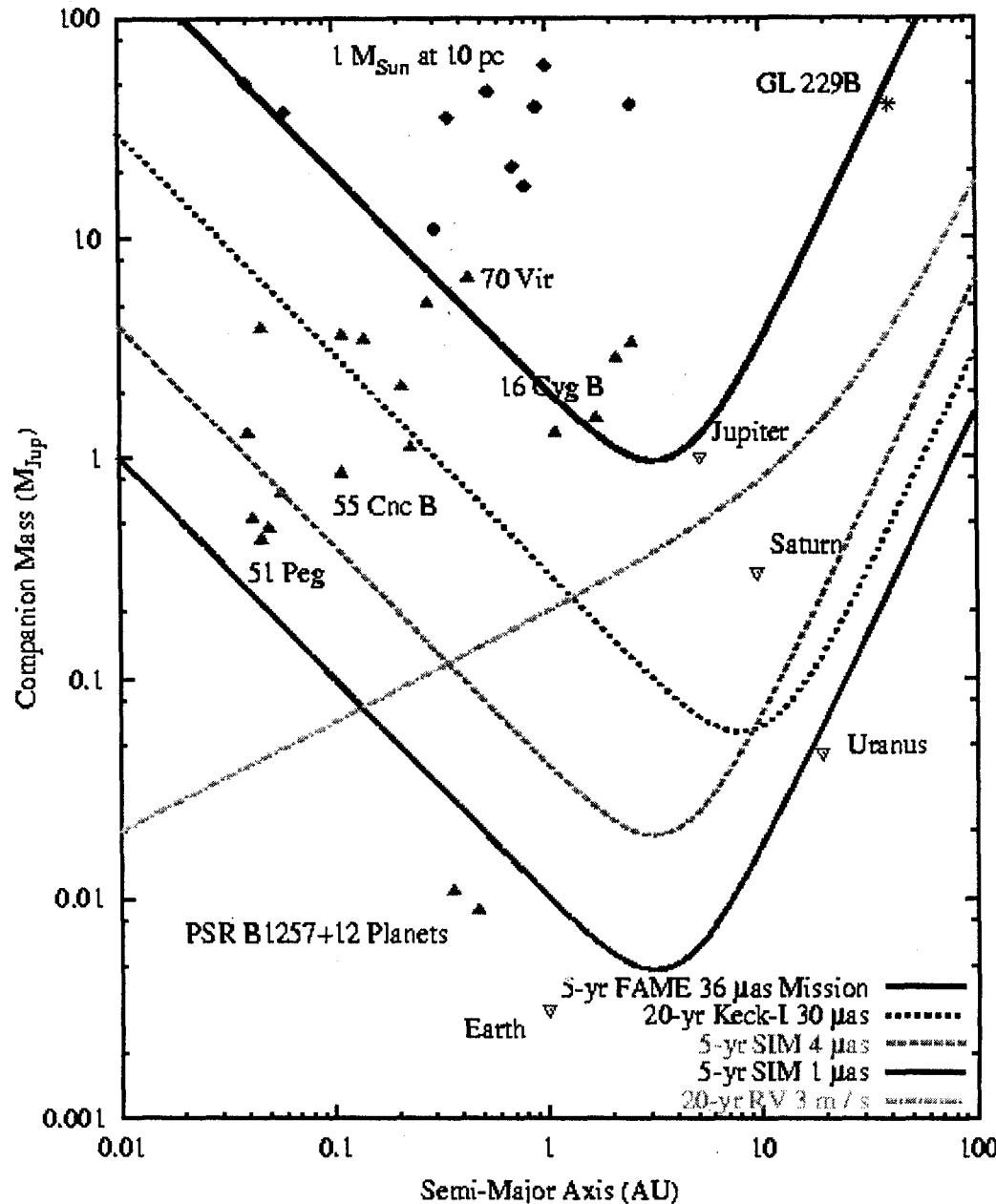


Astrometric Exoplanet Detection

- Science objective
 - Survey 100's of nearby stars for planets to Uranus mass
 - Uses outrigger telescopes for long-term survey
- Observational issues
 - High-accuracy narrow-angle astrometry ($30 \mu\text{as} \sim 2 * 10^{-10} \text{ rad}$)
 - Nominal $K=17$ isoplanatic ref. (Approx 50% sky coverage)
- Architecture
 - Four 1.8-m outriggers
 - Orthogonal ~100m baselines
 - Dual-star feeds
 - End-to-end laser metrology
 - $30 \mu\text{as}$ per hour accuracy for differential astrometry

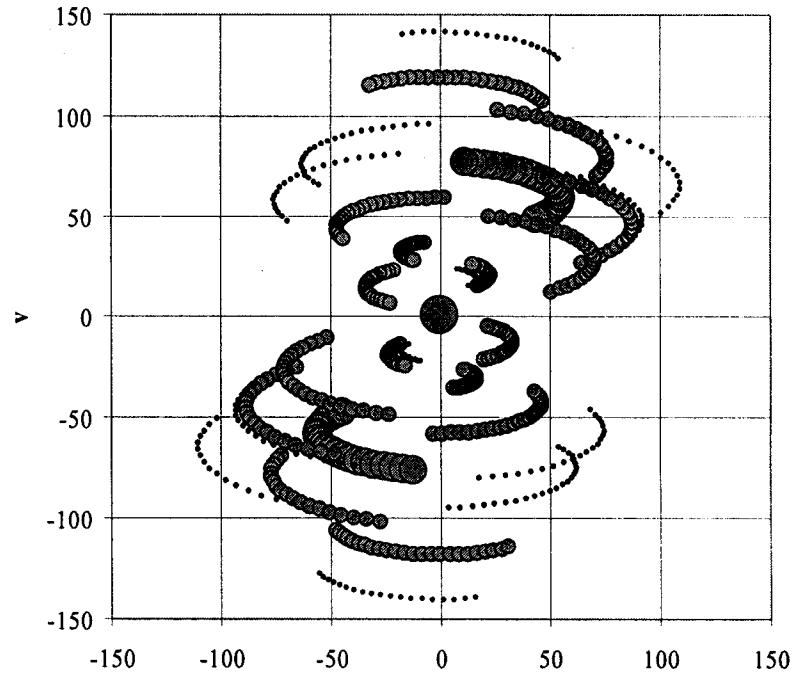


Space for Exoplanet Detection



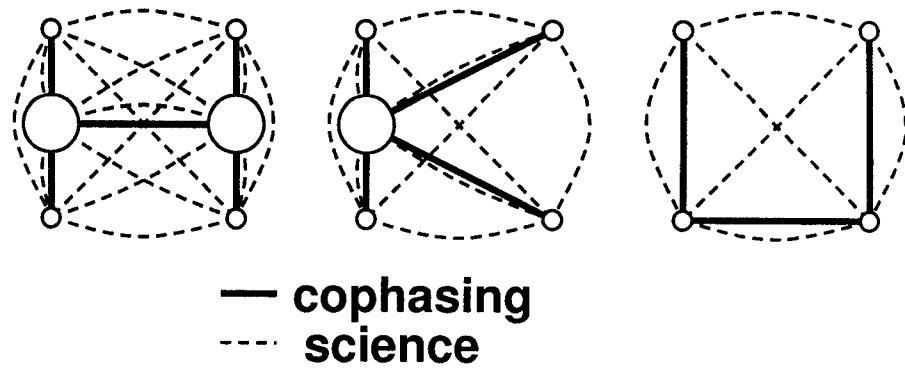
Synthesis Imaging

- Science/Instrument objectives
 - Imaging with 6-element array
 - Good (u,v)-plane coverage
- Observational issues
 - 9 of 15 baselines include a 10-m telescope
 - Background-limited sensitivity equivalent to two 4.4-m's
 - Other imaging options using OTs with 1 or 0 Kecks
 - Use cophasing to increase sensitivity
- Ultimate sensitivity
 - K-K fringe tracking: $K=14.1$
 - OT-OT fringe tracking: $K=10.8$
 - Cophased imaging
 - $K=19$ for SNR >10 in 1000 s on a Keck-OT baseline
 - Requires $K=11.6$ isoplanatic ref



u,v coverage with outriggers and Kecks
(width of line indicates baseline)

Science and cophasing baselines

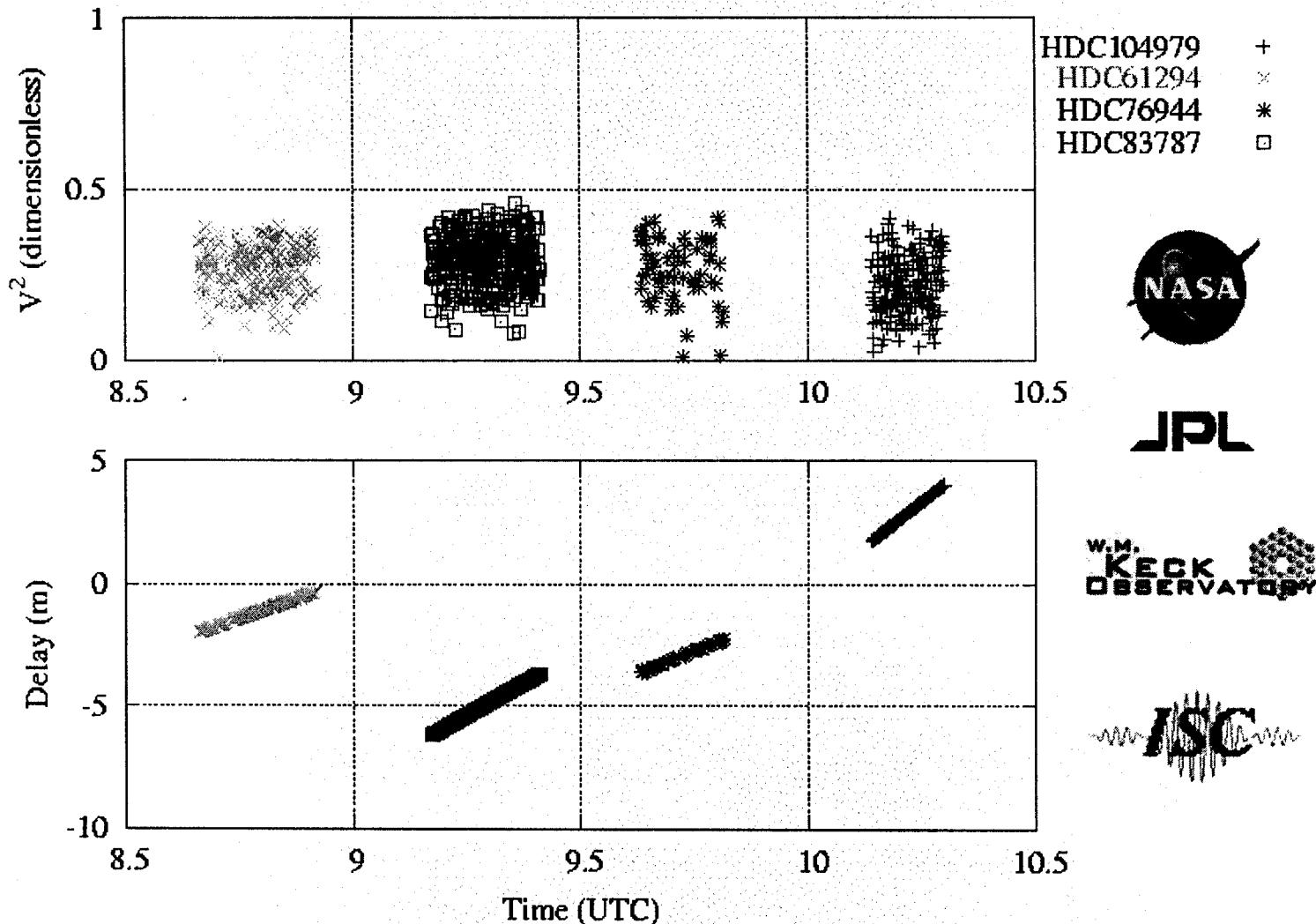


Keck Interferometer Elements

- Infrastructure
 - Basement Lab
 - Outrigger site work
- Telescopes
 - K1+K2
 - K2 AO + new K1 AO
 - Outrigger telescopes and domes
 - Dual star modules
 - Coude trains
 - Siderostats (for first fringes)
- Beam handling
 - Beam tunnels and pipes
 - Transport optics
 - Long delay lines
 - Fast delay lines
 - Beam switchyard
- Starlight subsystems
 - Fringe tracker
 - Angle-tracker
 - Nuller
 - 6-way combiner
- Other subsystems
 - Laser metrology
 - Auto-alignment system
- Computer components
 - Embedded control software
 - Interferometer and telescope sequencing software
 - User interfaces
 - Observation planning, monitoring, analysis tools (ISC)

KI First Fringes -- March 12

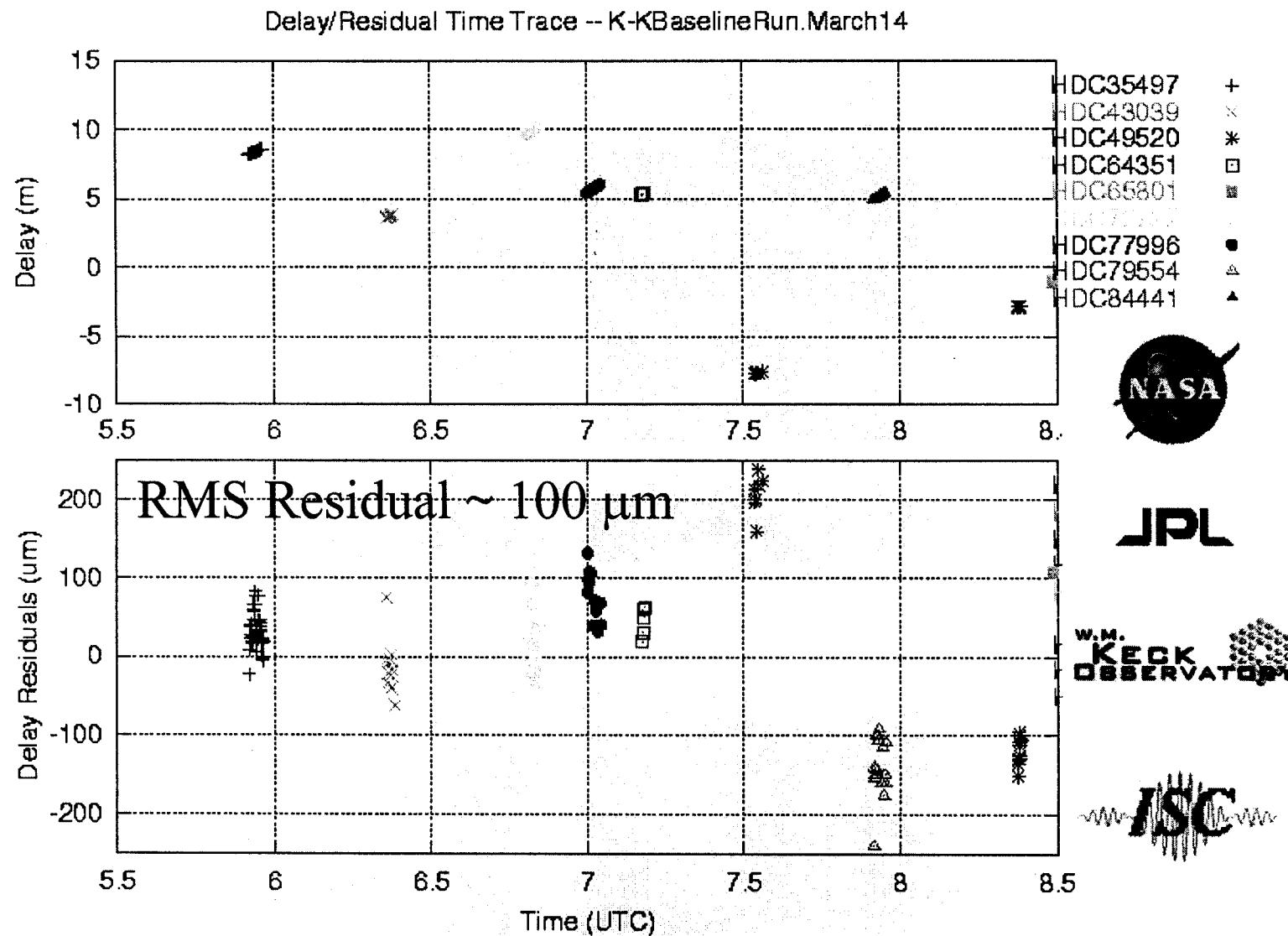
First fringes with Keck Interferometer -- March 12, 2001



FF With Siderostats: Feb 22

FF With AO-corrected Kecks: Mar 12

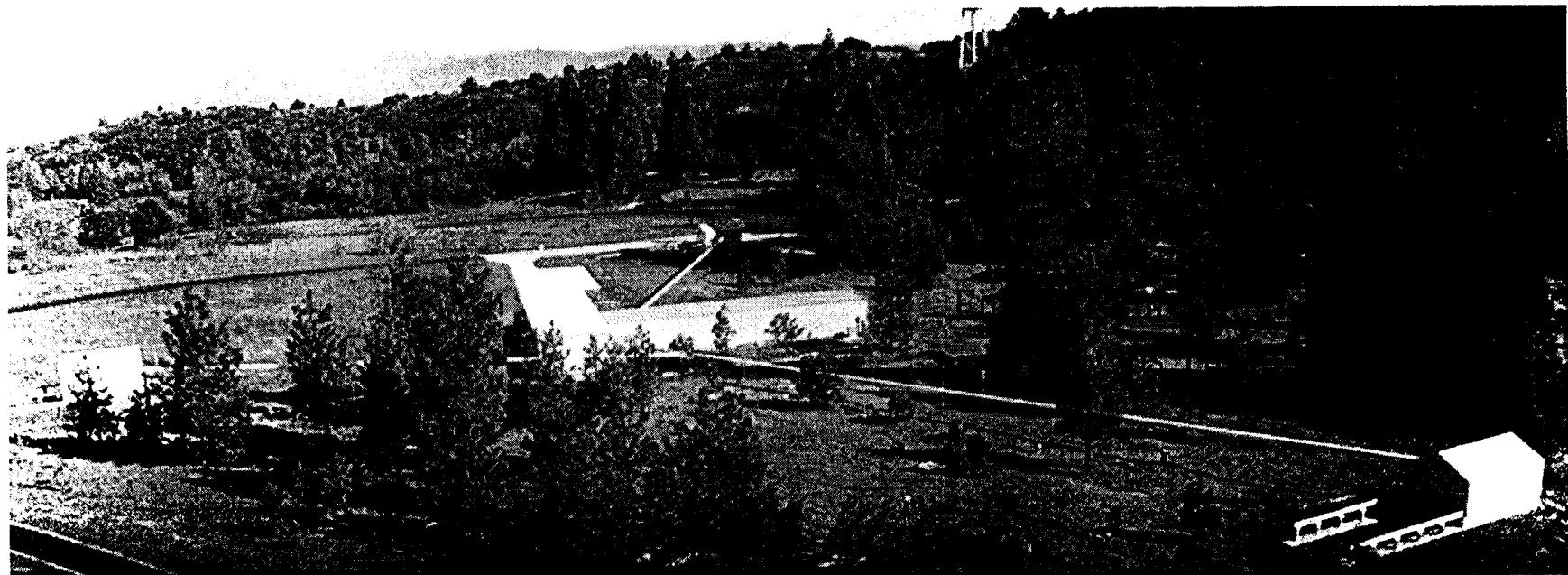
First Baseline Run -- March 14



KI Science Prospects

- KI NASA Research Announcement Released April 13
 - Shared risk (V^2) and debugging (DP/Nulling) science in 2001 & 2002
 - In partnership with development team (JPL/ISC/WMKO)
 - Likely V^2 scientific priorities:
 - ❖ AGN
 - ❖ PMS Stars
 - ❖ Galactic Center
 - DP & Nulling programs still to take shape -- Dec 2001
- KI Phase Referencing and Astrometric Capability Expected 2003
- Synthesis Imaging Expected 2004

Palomar Testbed Interferometer (PTI)



PTI is a Near-IR (K & H-band)
single-baseline interferometer

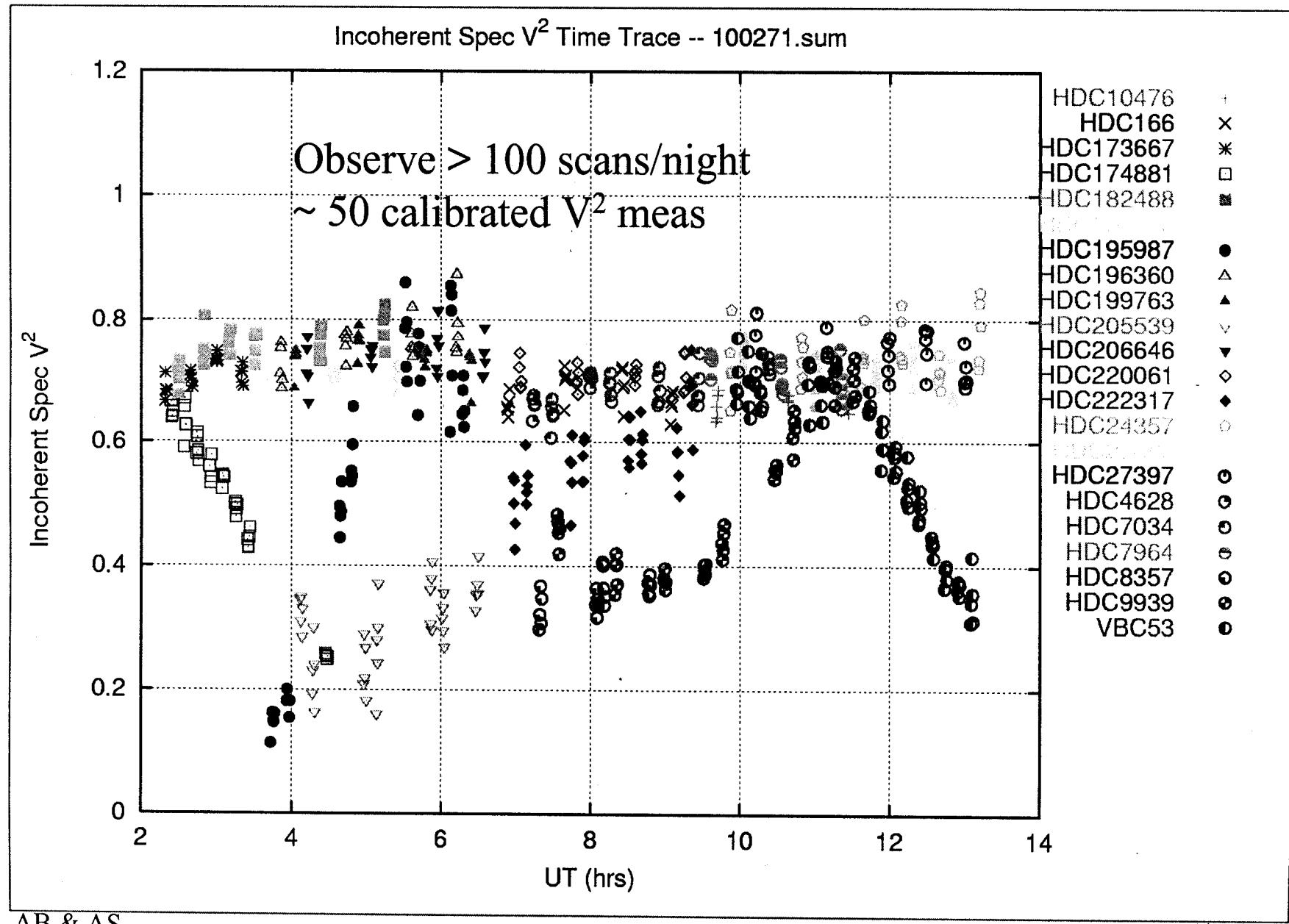
- NS and NW baseline combination
- NICMOS array combiner
- Point Src Limiting Mag K ~ 6.5
- Scientific Limiting Mag K ~ 5.6

URL -- <http://huey.jpl.nasa.gov/palomar>

➤ Single and Dual-Beam
Interferometry:

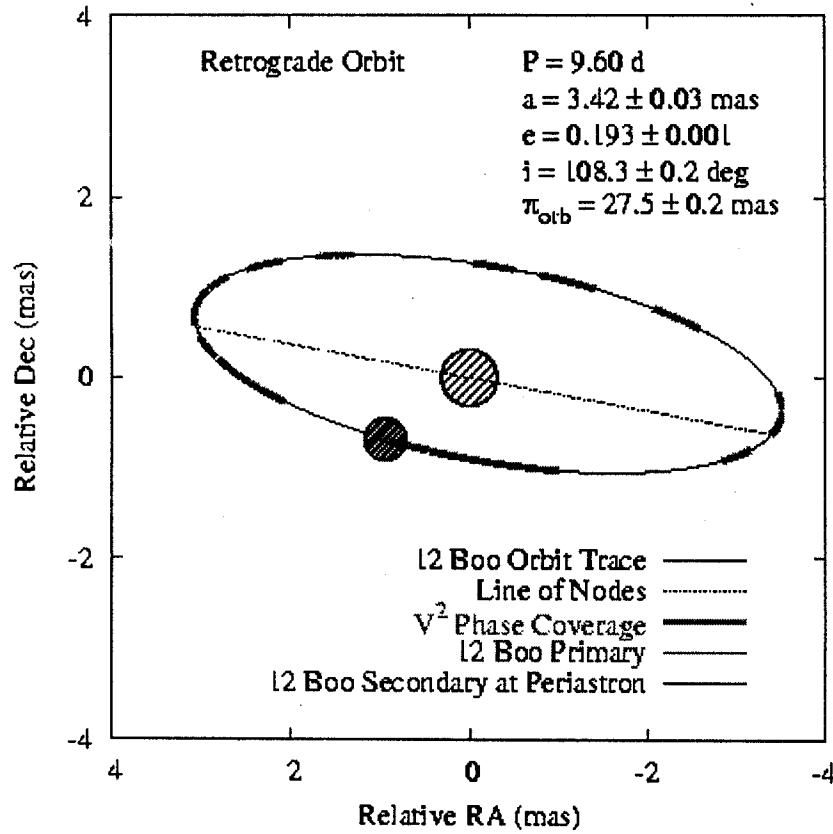
- Visibility (V^2) measurement =>
modelling (simple morphology
like one or two stars)
- Simultaneous fringe tracking on
two nearby stars => differential
astrometry

A "Typical" Night of PTI V² Data...

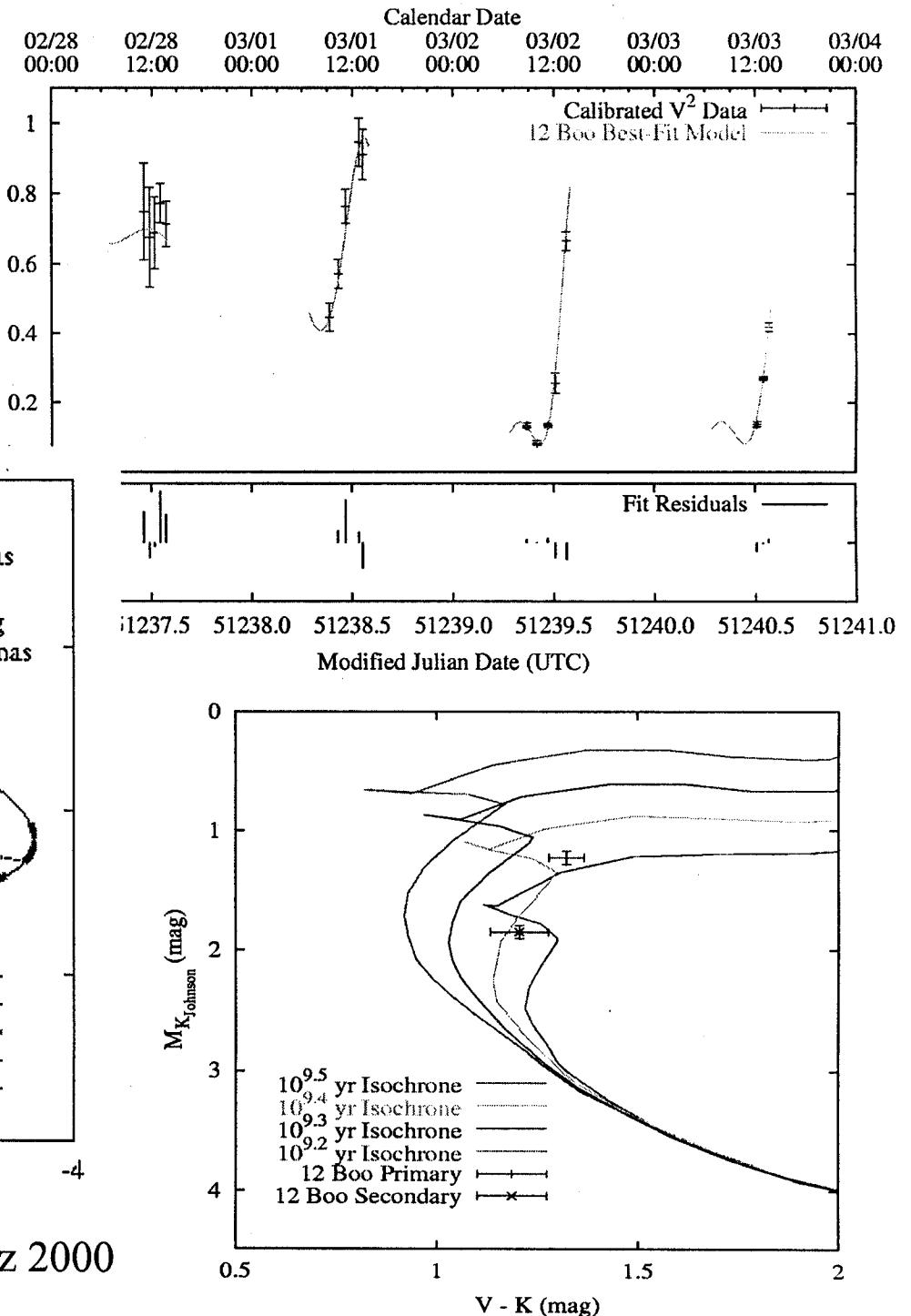


Short-Period Binary Stars

Objectives: stellar parameter
(M, L) determination, tidal
interaction studies

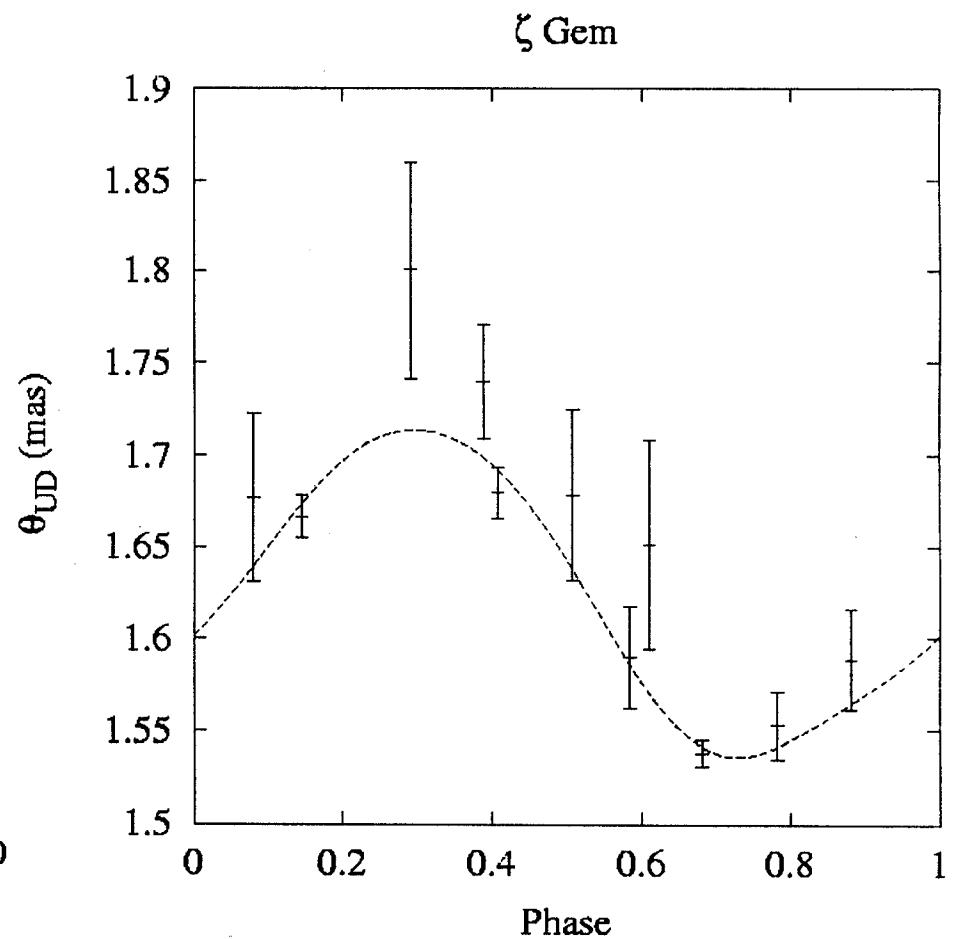
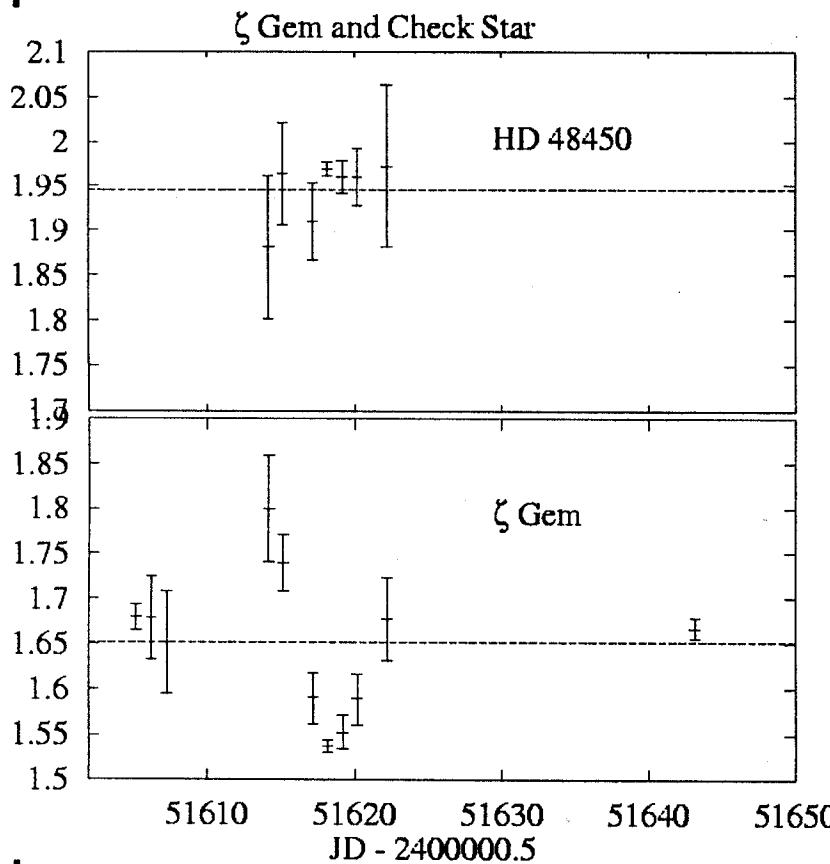


e.g. Boden, Creech-Eakman, & Queloz 2000
AB & AS



Cepheid Pulsations

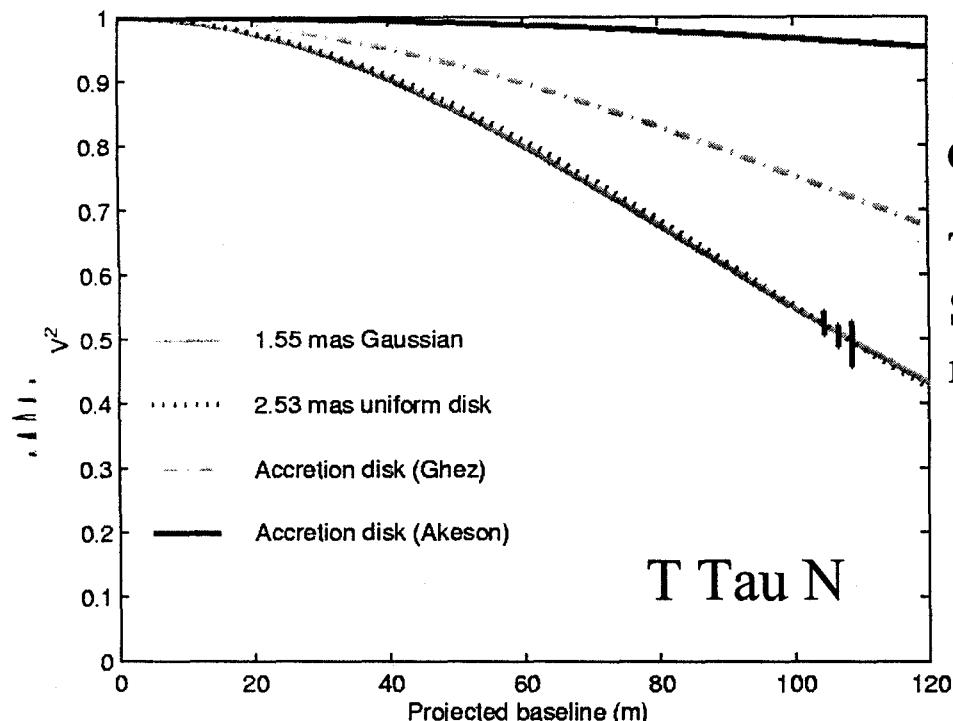
Objectives: Direct detection of cepheid pulsation; Inference of distance through Baade-Wesselink method



Lane et al 2000, Nature 407, 485

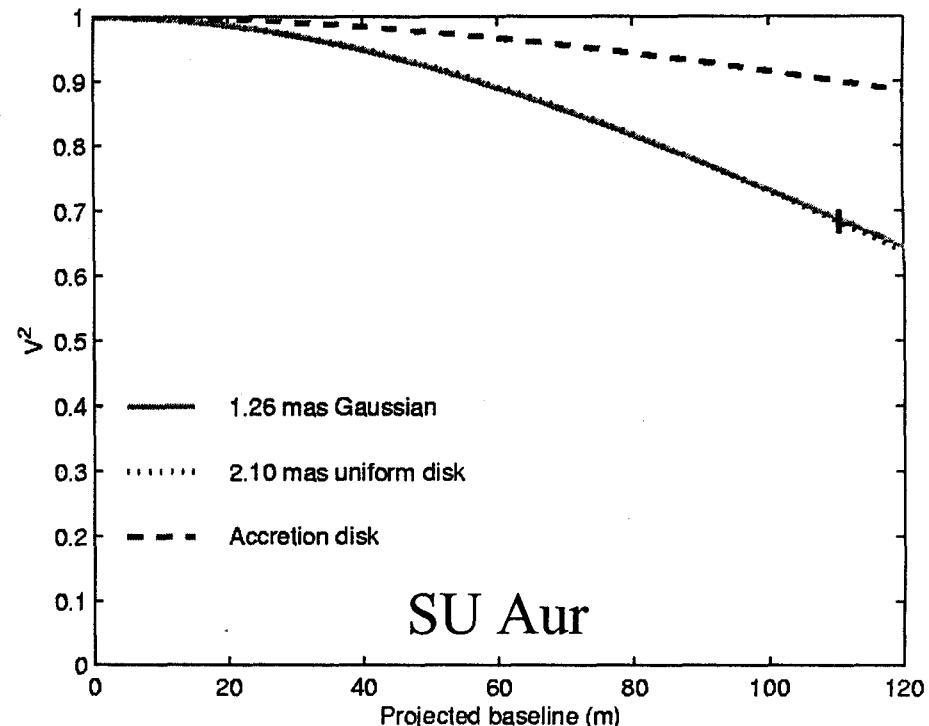
YSO Observations

Objectives: Characterization
of T Tauri circumstellar inner
disk (< 1AU) properties



1999 PTI Observations
of YSOs

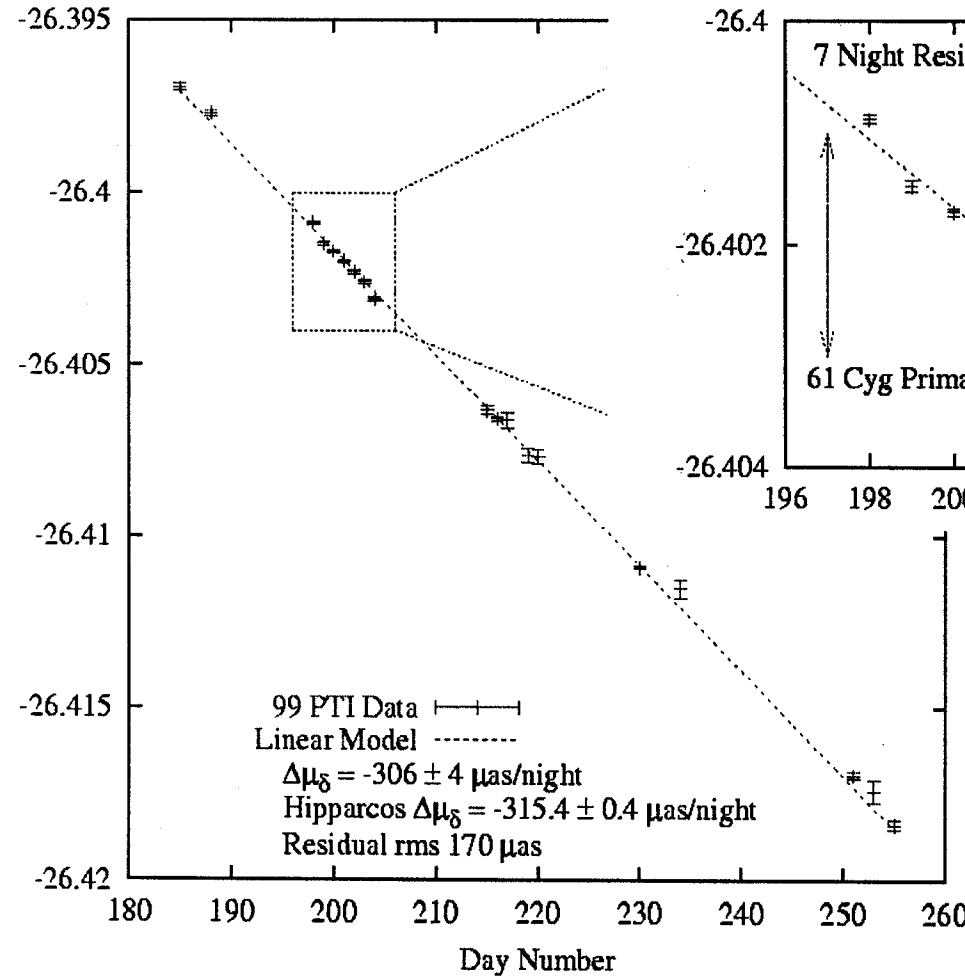
T Tau N Models:
SED Modeling (Ghez et al 1991)
mm Emission (Akeson et al 1998)



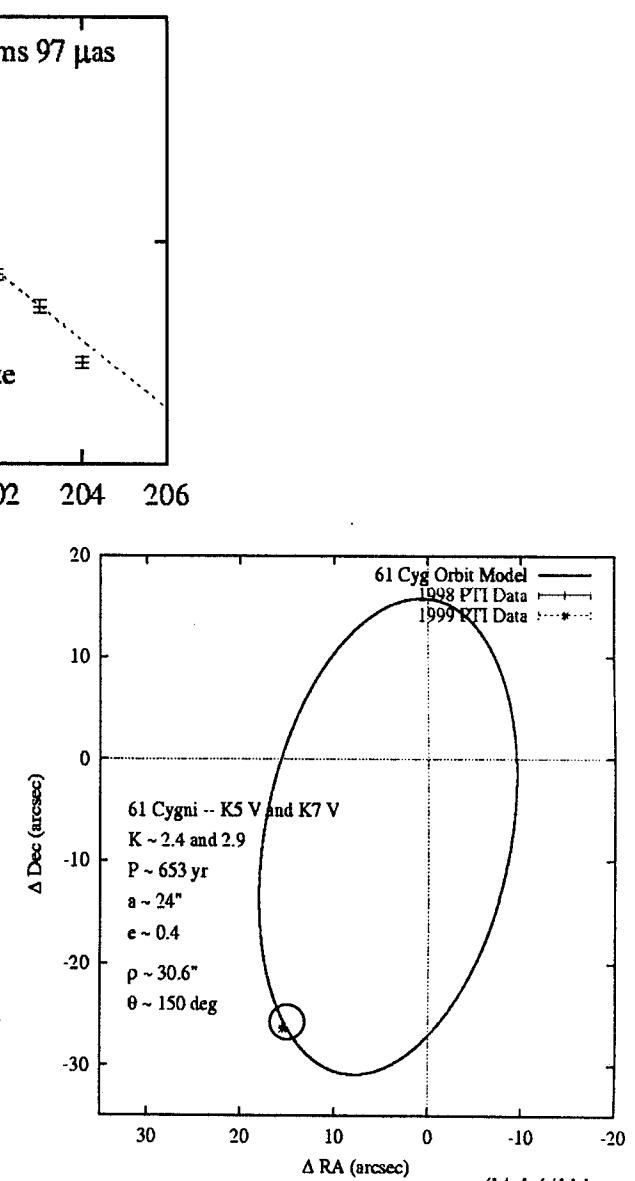
Akeson et al 2000, ApJ 543, 313

PTI Astrometry on 61 Cygni

Objectives:
High-precision relative
astrometry demonstration



100 mas precision differential astrometry demonstrated at PTI



PTI Summary

- PTI has advanced/demonstrated stellar interferometry technology on several fronts:
 - Automated operation (MkIII, NPOI)
 - Differential phase
 - Dual-beam interferometry
 - ❖ Astrometric measurements
 - ❖ Phased-reference operation
- PTI Science
 - Cepheid studies (Lane, Kuchner)
 - Stellar diameters (van Belle et al)
 - Short-period binary stars (Boden, Koresko, Lane)
 - Miras (Thompson, Creech-Eakman)
 - YSOs (Akeson, Malbet)

URL -- <http://huey.jpl.nasa.gov/palomar>

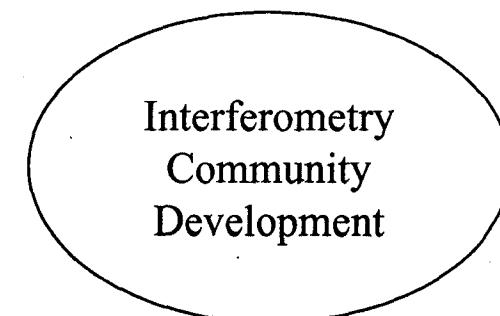
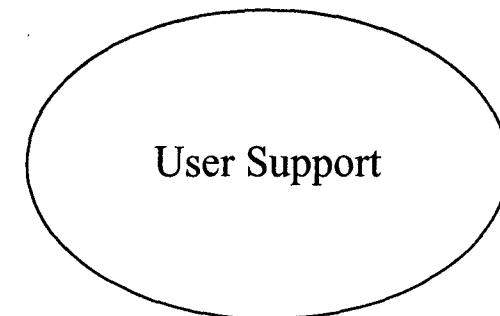
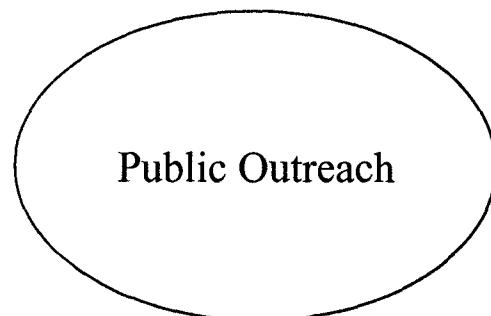
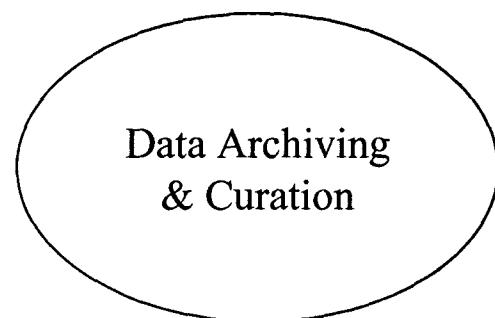
ISC Charter

- The ISC is a service organization created to facilitate the timely and successful accomplishment of the science objectives of NASA Origins interferometers. The ISC's goals and roles in pursuit of this objective are:
 - Enabling users to produce meaningful scientific results using observations from the missions and facilities supported by ISC.
 - Ensuring efficient utilization of the missions/facilities supported by ISC.
 - Cultivating a broad user community and increasing the awareness of scientific opportunities provided by these missions.
 - Archiving and curating the observations from these missions for future scientific use.
 - Improving ease of use and reduce costs of science operations systems for projects by utilizing common resources and methodologies.

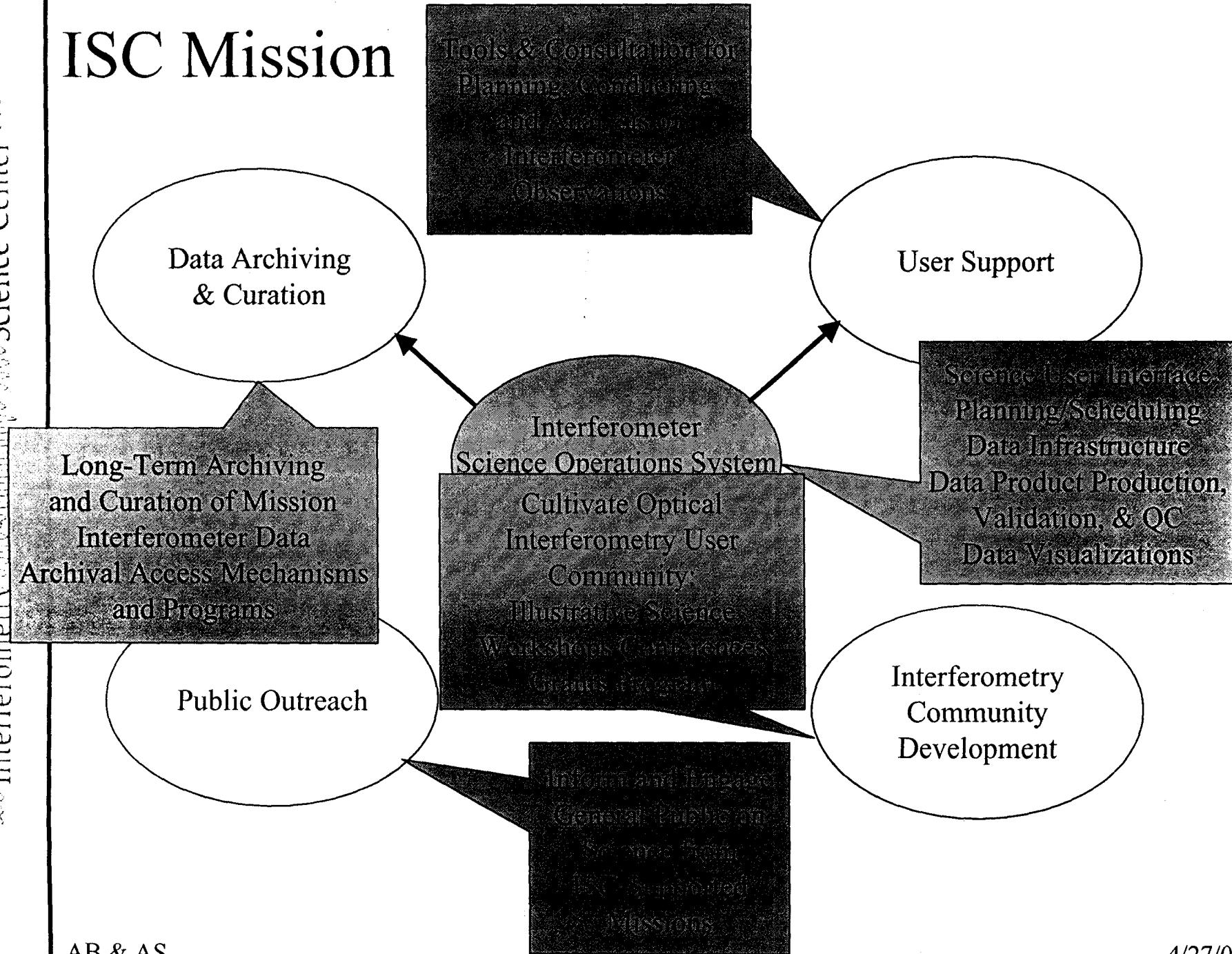
Supported Projects

- Keck Interferometer (KI -- and PTI)
- Space Interferometry Mission (SIM)
- StarLight (Former DS3 -- Separated Spacecraft Interferometry)
- Terrestrial Planet Finder (TPF)

ISC Mission



ISC Mission



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